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DEPARTMENT OF INTERNAL AFFAIRS
James F. Woodward, Secretary.

TOPOGRAPHIC AND GEOLOGIC SURVEY

George H. Ashley, State Geologist.

GAS IN THE TIOGA REGION, PENNSYLVANIA.

By

Stanley Holman Cathcart and Bradford Willard.

STATUS OF DRILLING, WITH NOTES ON GEOLOGY.

by

Stanley Holman Cathcart.

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Introduction. In June 1930 the Allegheny Gas Company, the producing organization of the North Penn Gas Company, began drilling a well on the Sabinsville anticline in Farmington Township, Tioga County. A large flow of gas was encountered at 4,012 feet on September 10, in what probably is the Oriskany sand. The well blew wild until brought under control by the Halliburton process, September 25, and was finally put on production October 11. Initial production was variously reported as 10 to 20 million cubic feet and the production after drilling out the cement as about 2 to 2½ million cubic feet a day.

Situated as it is near the east edge of the Allegheny Plateaus, this well was essentially a "wildcat." Forecasts based upon past experience in and general geological understanding of the

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region could anticipate no greater success for the test than a possible small oil well or a probable small to moderate-sized gasser. Bringing in a well of such capacity as this one, therefore caused correspondingly great excitement that was felt far beyond the boundaries of Pennsylvania. Representatives of oil and gas companies and independent leasers flocked to the scene of the strike and began leasing immediately. Lease operations extended throughout the entire adjacent country in Pennsylvania and New York, so that by middle December more than 2,500 leases had been recorded in Tioga County, 800 in Potter County, and many more in Clearfield, Cameron, Clinton, Lycoming, Sullivan, Bradford and Susquehanna counties. Fortunately the leasers included a fair proportion, at least, of seriously interested and responsible companies and individuals, so that, even before the initial well was brought under control, additional test wells were being planned, and within 3 months, ten other locations have become active, one of which is nearing completion.

Status of developments in mid-December, 1930. When the region was ~~visited by the writer for the Pennsylvania Geological~~ Survey, December 17 to 19, eleven locations were active, and at least one other location was under consideration. Pertinent data relative to these locations are tabulated below. Geographic location and approximate structural position of the wells are shown on the accompanying map. All of the wells start in the Chemung group of sandstones and shales of Upper Devonian age.

Standard rigs are in use on all locations. With the exception of one well all have started with 10-inch holes. Common practice is to run 100 to 200 feet of 10-inch surface pipe, to set 750 to 900 feet of 8-inch casing, and to cement 4,000 feet ≁ of 6-inch casing above the "Oriskany." The Close well has been started with larger hole in anticipation of drilling deeper should the "Oriskany" prove to be nonproductive. Eighteen feet of 16-inch and 1,000 feet of 10-inch has been run.

Drilling is not difficult. Commonly a water-bearing sand is encountered within the first 100 to 300 feet and little additional water is met before the 8-inch casing is set. After setting the 8-inch casing, the wells are drilled practically dry and give little or no trouble from caving or crooked hole. Drillers' logs are kept on all wells and in the case of the three Lycoming Natural Gas Corporation wells, samples are taken at frequent intervals. The formation drilled is variously logged but probably most of it would fall within the classification, sandy shale and shaly sandstone. Relatively little true shale, lime or sand is logged in the Chemung section and such strata as are so logged do not seem to persist between locations as they now are spaced. The only logical horizon marker yet known that should prove useful in controlling the depth of the well is the Onondaga lime, 25 feet of which is logged in the Palmer well as immediately overlying the producing sand (see log below).

The cost of drilling a well to the "Oriskany" in this area is estimated to be $13,000 to $16,000. The time required will probably range between 1½ and 2½ months.

As intimated above, most of the acreage adjacent to the wells now drilling has been leased. Some acreage has been acquired outright. Almost every conceivable sort of lease bargain has been employed in securing leases. Annual rentals are said to range between 25 cents and $10.00 an acre. The royalty clause may call for from $100 to $500 for a gas well, or in some instances specify 2≁ cents per 1,000 cubic feet or 1/8th of production. One lease calls for $5.00 cash consideration, a well within 6 months, and 1/8

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Drilling operations in Tioga County, Pennsylvania.

Name of Well		No. on Map	Reported owners	Town-ship	Quad-rangle	Apprx. elev.	Depth reported mid.Dec.	Status
Palmer	#1	1	Allegheny Gas Co.	Farmington	Tioga	1730	4012	Producing gas well.
Kemp	#2	2	" " "	"	"	1730	4300	Running $6\frac{1}{4}$" casing.
Bostick	#1	3	J. E. Trainor	Lawrence	"	1510	650	Drilling.
Farr	#1	4	J. C. Trees	"	"	1320	500+	"
Howe	#1	5	Lycoming Nat.Gas Corp.	Farmington	"	1740	1960	"
Meaker	#1	6	Frank Brendel	Tioga	"	1650	2300	"
Chumacker	#1	7	Lycoming Nat.Gas Corp.	Lawrence	"	1460	1100	"
Adams	#1	8	Adams Gas & Oil	Charleston	"	1330	2800*	Reported "to be deepened."
Close	#1	9	Penn Ohio Gas Co.	Farmington	Elkland	1780	1300	Drilling.
Price	#1	10	Benedum & Trees	"	"	1720	150	"
Bertch	#1	11	Segar Oil & Gas Co. and Hope Eng. Co.	Brookfield	Gaines	1830	3052**	Rigging up to deepen
Ackley	#1	12	Lycoming Nat.Gas Corp.	Clymer	"	1925	270	Drilling

*Old well on Adams farm drilled 12 years or more ago to depth variously reported as 2800 - 3800 feet.

**Old well on James Bertch farm drilled about 10 years ago.

royalty. Cash bonuses were paid in many instances on first year rentals. Leases are commonly for terms of 10 to 20 years, but some leases that emphasize immediate drilling are for a shorter term.

The Discovery Well. The discovery well, Palmer No. 1 of the Allegheny Gas Company, appears to be located near the axis of the Sabinsville anticline, but the relative structural height of the fold at this latitude is not determinable from government surveys. Stratigraphically the well appears to begin about 1,000 feet below the top of the Chemung group. The producing horizon, as judged by material blown from the well, is sandstone that is said by actual test to show 11 per cent porosity. The stratigraphic succession indicated by the driller's log of the well and the apparent thickness of the strata penetrated suggest that this is the Oriskany sandstone.

When visited in December, the well was reported to be producing in excess of 2 million cubic feet daily, to show a shut-in pressure of 1,650 pounds and an open flow pressure of 520 pounds. The gas is reported to be of good quality. A driller's log of the well is given below:

Log of Palmer No. 1 gas well, Tioga County, Pennsylvania.

	From	To		From	To
Slate, gray, (light)	0	260	Broken sand, gray	1741	1756
Sand, gray, (light)	260	267	Slate & shells, gray	1756	1830
Slate, gray, (light)	267	275	Shale, dark gray	1830	1842
Sand, gray	275	280	Slate & shells, gray	1842	1995
Slate, gray, (dark)	280	380	Slate, gray	1995	2030
Sand, gray	380	390	Shale, light gray	2030	2050
Shale, (dark gray)	390	457	Sand, gray	2050	2070
Sand, (dark gray)	457	465	Slate & shells, gray	2070	2090
Sand & shells (lt.gr.)	465	695	Sand, gray	2090	2097
Slate, gray	695	865	Slate & shells	2097	2125
Shale, dk. gr.-lit.gas	865	950	Slate, black	2125	2270
Shells, gray	950	967	Sand, gray	2270	2296
Sand, gray	967	975	Shell, gray	2296	2312
Shale, dark gray	975	1005	Slate, gray	2312	2330
Sand, dark gray	1005	1012	Broken sand, gray	2330	2360
Slate & shells, gr.dk.	1012	1050	Sand, gray	2360	2371
Slate, light gray	1050	1065	Shale, gray	2371	2392
Slate & sand, lt.gr.	1065	1078	Sand, dark gray	2392	2405
Slate, dark gray	1078	1145	Shale, gray	2405	2434
Sand, dk. gray, lit. gas	1145	1160	Sand, gray	2434	2445
Slate, light gray	1160	1285	Slate & shells, lt. gray	2445	2470
Shale, black	1285	1297	Sand, gray	2470	2595
Slate, dark gray	1297	1370	Lime, gray	2595	2605
Sand, light gray	1370	1384	Shale, dark gray, with pyrite	2605	2654
Slate, shale, shells, bk	1384	1560	Slate & shells, gray	2654	2667
Sand, gray	1560	1592	Slate, dark gray	2667	2690
Broken sand, gray	1592	1615	Shale, dark gray	2690	2765
Sand, gray	1615	1622	Slate & shells, dk. gray	2765	2777
Broken sand, (dk.gr.)	1622	1690	Shale, gray & black	2777	3015
Shale (dk.gr.)	1690	1696	Lime, sandy, gray	3015	3100
Shells, gray	1696	1705	Shell & lime, dark gray	3100	3120
Slate, gray	1705	1716	Shale, dark gray	3120	3180
Broken sand, gray	1716	1735	Shale, gray	3180	3500
Sand, gray	1735	1741	Lime, gray	3500	3557

	From	To		From	To
Shale, dk.gr.w. pyrite	3557	3930	Lime, dark gray	3995	4005
Pyrite, black	3930	3940	Sand, gray, hard, crsk.	4005	4010
Pyrite, limey, black	3940	3950	Sand, gray, hard, crsk.	4010	4010½
Shale, calcareous	3950	3970	Sand, gray, hard, crsk.	4010½	4012
Shale, black	3970	3980	150,000 cu.ft. gas		
Lime, slaty, black	3980	3987	300,000 " " "		
Lime, sandy, black	3987	3995	12,000,000 " " "		

Literature. All of the wells listed above fall within the area that is included in two folios of the Geologic Atlas of the United States published by the U. S. Geological Survey, namely, the Gaines folio covering the Gaines quadrangle and the Elkland-Tioga folio covering the Elkland and the Tioga quadrangles. These folios are out of print, but can be consulted at libraries. They present the general geology of this region and show by 100-foot contours on the top of the Chemung the character of the major structural features in most of the area that they cover.

The geology of the region adjacent to the area covered by the folios is mapped and described in publications of the Second Geological Survey of Pennsylvania. These publications also are out of print but may be consulted in libraries.

Topographic maps of the Gaines, Elkland, and Tioga quadrangles may be procured from The Director, U. S. Geological Survey, Washington, D. C., for 10 cents each.

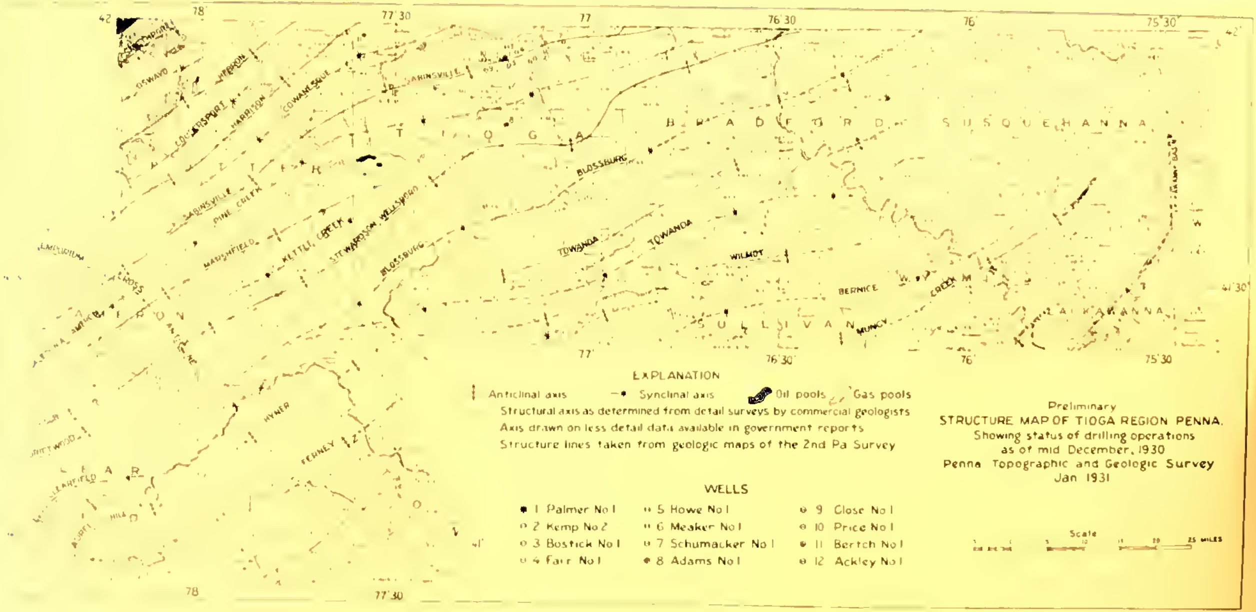
County maps of Tioga, Potter, Susquehanna, Sullivan, Lycoming, Clinton, and Cameron counties may be obtained from the Pennsylvania Highway Department for 50 cents each.

The accompanying map attempts to outline the major structural features of the Tioga and adjacent regions, and to show the geographic position of the well locations referred to in this text. The structural data are compiled from government and commercial sources.

Notes on Geology.

The drilling situation. Each location that is now active is near the axis or on the flank of an anticlinal structure, but the geological data available do not permit us to define accurately the relative stratigraphic and structural favorability of the several locations.

The structures being drilled are very definite folds that have broad crests and show flank dips of the order of magnitude 8 to 12 degrees. They appear to be essentially symmetrical, but with somewhat steeper east than west limb. The axes trend north of east, are sinuous and plunge and rise to form a series of domes and saddles. The amplitude of the several folds that occur in the Gaines, Elkland and Tioga quadrangles is shown by the structure contour map that is included in the folios covering those quadrangles.



Preliminary
STRUCTURE MAP OF TIOGA REGION PENNA.
Showing status of drilling operations
as of mid December, 1930
Penna Topographic and Geologic Survey
Jan 1931

Contours are drawn on the top of the Chemung, which horizon is as much as 1,900 feet higher on the anticline than in the adjacent synclines.

Erosion of the folds has resulted in broad belts of Chemung being exposed on the crests of the anticlines. The Catskill contact commonly appearing far down on the flanks of the anticlines.

That part of the Chemung exposed at the surface consists chiefly of sandy shales and shaly sandstones with occasional thin beds of limestone. No well-defined horizon markers are known that would serve as reliable key beds in mapping this Chemung area. Moreover, while there are many excellent exposures on the steepened flanks of the folds on the broad crest of the fold where dips are relatively flat exposures are few.

It is because of these three factors, namely, absence of good key horizons in the Chemung, scarcity of outcrops near the crest of the fold, and distance of the Catskill contact from the anticlinal axial areas, that it is difficult to determine, without doing detailed and specially directed work, just where the various locations are with respect to structure and stratigraphy. This is a subject of no little importance. One gas well does not make a gas field, but the locations now active should do much to tell the story in this region, provided the holes drilled are well placed, that their relation to structure is known, and that each reaches its objective. To place properly a well in this area requires careful geologic work. To prove the area, axial highs, saddles, terraced flanks and synclines all should be given a chance to contribute their share of information. The matter of objective is equally important. We know little about the sands of the Chemung, but the general lithologic aspect of that formation suggests very strongly that lenticular strays are to be expected at any horizon, and shows of gas encountered in wells now drilling indicate that such strays may carry some gas. It is improbable, however, that such sands will prove to be commercial, and from the standpoint of proving the field that is implied in the success of Palmer No. 1, all wells should reach the Palmer No. 1 producing horizon.

The identification of the producing horizon of Palmer No. 1 should not prove difficult, provided the "Onondaga" lime is persistent throughout the area. Should it fail to serve as an infallible key horizon, then appearance of gas sands among the overlying beds or lensing out of the Palmer No. 1 producing horizon may prove difficult of interpretation, unless some more scientific method of correlation than the one now in use is developed for these horizons.

It goes without saying that the most serious error possible in "wildcat" development of this kind is to stop a well-located hole too soon. Due consideration should be given to the fact that it would be very easy to make an error of 100 feet in deciding at what stratigraphic horizon in the Chemung a well starts, that allowance should be made for thickening in a series of sediments of Chemung lithology, and that in the absence of productive sand at the Palmer No. 1 producing horizon, production might be expected at a somewhat deeper horizon. In addition, while faulting is not known to deserve serious consideration in this area, the fact remains that in any region of folding, stratigraphic thicknesses are likely to be appreciably modified at certain localities by multiple small slips or adjustment folds.

Petroleum possibilities. As outlined by State Geologist Geo. H. Ashley in a press notice issued October 2, 1930.

"The oil and gas region of Pennsylvania may be divided into four belts: first, a northwestern belt including Erie, Crawford, and northwest Mercer counties with small production of oil and gas, due mainly to the thinning out in this area of most of the sandstones that serve as reservoirs; second, the oil field proper, lying east and south of the first belt, in which the oil and gas occur. Its eastern boundary runs from northeast McKean County southwestward past Clarion, Redbank and a little east of Pittsburgh to the southeast corner of Greene County; third, the gas belt, lying east of the oil belt and west of a line through Coudersport, DuBois, thence to crest of Chestnut Ridge and south along that ridge; fourth, a belt between the line just drawn and the crest of Allegheny Mountain covering the eastern and northeastern coal counties and the northern counties to Delaware River."

The Tioga development is in the fourth belt, where until recently, notwithstanding the fact that much drilling had been done, with few exceptions only small amounts of gas had been discovered. This belt corresponds to the area of low volatile coals. It is believed that a rather definite relationship exists between the quantity of volatile matter in coals, the petroleum content of strata and the intensity of folding in any given area. Commonly where the volatile content of coals associated with petroleum-bearing beds does not exceed 35 per cent, which in general is true for this fourth belt, the chance of finding commercial production is considered to be small. However, at least one source of exception is ever present, namely, that within so large an area folding has not everywhere been of the same intensity, and as a result, islands, so to speak, of favorable territory may occur within a region that otherwise has little promise in a commercial way. As coals do not underlie this entire belt such relatively favorable areas may be present where coals are absent, and the method thus fails in applicability.

Basing opinion upon actual results of drilling in the area and upon relation of petroleum production in Pennsylvania to isovols (lines representing average volatile content of coals in the region), but remaining conscious of the limitations of the isovol data, this Survey has repeatedly maintained that most of this fourth belt is gas territory, but that it is on the whole unfavorable to commercial oil and gas production. That is, while isolated pools of gas or even oil may exist within the area, the area as a whole probably will not return the cost of prospecting. To state the contention quantitatively for clarity's sake, but without pretending to estimate actual odd, we might say that whereas, in the oil and gas belt proper a prospector's chance of finding commercial production may be 50-50, within this region his chances are likely to be no better than 100 to 10 or 5 or even 1.

Further, it is probable that gas rather than oil will be encountered in this belt, that the possibilities of finding oil will decrease in going east (or southeast) in this belt, but that oil if found will be of high grade, and that gas will become less plentiful in going from west to east.

Gas is produced in Ohio and Kansas* where the carbon con-

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*Lilley, E. R., Geol. of Pet. and Nat. Gas, p. 113, 1928.

tent of pure coal reaches 80 per cent, that is, volatile matter 20 per cent, but this occurrence is exceptional rather than common. The line representing 20 per cent volatile matter in coal of this region runs approximately through Towanda and Lock Haven. We cannot say that gas will not be found this far east in Pennsylvania, but merely that in looking for commercial production east of this line the prospecting hazard is unduly great.

In thus appraising the region we have in mind one function of the Geological Survey, namely, to inform prospective investors in "wildcat" enterprises what the chance would seem to be for success in those enterprises.

PROBABILITY OF THE OCCURRENCE OF THE ORISKANY SANDSTONE IN THE TIOGA REGION.

by

Bradford Willard.

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Introduction. The productive sand in the new gas development near Tioga is reported to be the "Oriskany." This assertion though probably true cannot be verified from present information. This paper discusses briefly the characteristics, distribution, and relations of this formation. Whether or not the Oriskany is the producing sand, the formation is fairly easy to recognize in conjunction with the immediately over-and underlying limestones, which makes it an important key horizon between the thick, monotonous Middle and Upper Devonian sandstones and sandy shales above and similar Silurian sandstones and shales below.

The Oriskany as a Datum Horizon.

Lithologic character and topographic expression. At the type locality, Oriskany Falls, New York, the Oriskany formation is a pure, light-yellow sandstone, loosely cemented and rather friable. From this type it varies from a fine conglomerate to a massive, blue-white chert, locally calcareous. Where massive it may form ridges or terraces, depending upon its attitude.

Faunal character. The Oriskany fossils are easily recognized and usually abundant. The most characteristic are brachipods. In New York State, and to a less extent in New Jersey and eastern and central Pennsylvania, the fauna, which can be conveniently called "northern" contains:

Rensselaeria ovoides (Eaton) Spirifer arenosus (Conrad)
Hipparionyx proximus Vanuxem S. murchisoni Castlenau

In southern Pennsylvania and Maryland the fauna consists of related but different species. Characteristic types of this "southern" fauna are:

Rensselaeria marylandica Hall Spirifer cumberlandiae Hall
S. concinnoideus Schuchert

These suggest dwarfed examples of the New York fauna. So far as known, there seems to be an absence of any microfauna which might be collected from well drillings.

Distribution. New York. The Oriskany is exposed as a nearly continuous, narrow band in central and eastern New York State. From its known, westernmost outcrop at the town of Newkirk about 50 miles east of Buffalo the trace is fairly regular eastward across the northern ends of Seneca and Cayuga lakes, where it is only 55 or 60 miles from the Tioga region. Except for a short break southwest of Syracuse, the outcrop trace extends as a sinuous band, with occasional short breaks, to the Hudson Valley, 11 or 12 miles southwest of Albany. From here it continues southward, as a very thin layer along the west side of the valley, nearly to Kingston. Thence it turns south-south-west past Port Jervis to enter Pennsylvania at Wallpack bend.

In Pennsylvania. The Oriskany has been reported, sometimes doubtfully, from nineteen counties. Its development varies. The lithology is not the same from place to place as it may be coarse sandstone, sandy shale, or flint, to shelly, calcareous or ferruginous beds; however, on the whole it is usually coarse, friable, light-colored sandstone. Entering the State at Wallpack bend, the outcrop forms Godfreys Ridge for 35 miles southwestward, which is continued in Carbon and Schuylkill countied under the name of Steinberg Ridge for 17 miles more. The trace becomes an irregular zigzag when it reaches Schuylkill River at Cresota, crossing and recrossing that stream, finally to be lost in Dauphin County. This disappearance seems due to faulting rather than lack of deposition, since it is again recognized at Susquehanna Gap. The formation is well developed in Perry County as a set of great zigzags outcropping for about 140 miles all told. In Juniata, Mifflin, Huntingdon and Blair counties it forms extensive outcrops, and then turns southward across the State line into Maryland.

The Oriskany has extensive development in the valleys of Susquehanna and Juniata rivers. Thus, it has been reported in Columbia, Northampton, Montour, Snyder and Union counties, although recent investigation casts some doubt upon some of these occurrences both as to their lithology and fossil contents. In this region the outcrops trend back and forth as great, sinuous lines following the mountain structures. It is significant that the formation is reported as patchy or lacking in Lycoming and Clinton counties, the district nearest the Tioga region. The Oriskany outcrops in Montour and Northumberland counties, and is reported in the region of Bellefonte.

Attitude and General Relations. From its outcrop, the Oriskany sandstone, if local variations in attitude be discounted,

descends generally toward the region of the New York-Pennsylvania boundary line. Thus, its dip is gently south in central New York, west in eastern New York, northwest in New Jersey and eastern Pennsylvania, and north to northwest in central Pennsylvania from its northern or westernmost outcrop. This is significant, since it at once becomes evident that, if the formation exists as a continuous sheet extending under the region bordered by its outcrops, it should pass beneath the Tioga field.

However, there are other factors to consider. We have observed that the outcrop is not continuous either in New York State or Pennsylvania. There are short breaks which are attributable to lack of original deposition or to subsequent erosion. A break in Dauphin and Cumberland counties, Pennsylvania is now attributed to faulting. We have also noted that the fauna differs over the region of distribution of the formation. Thus, a "northern" type occurs in New York, New Jersey and eastern Pennsylvania, a "southern" is recognized in south-central Pennsylvania and Maryland. In the upper Juniata Valley and southwestward there appears to be a mixing of these faunas. A typical New York series occurs in Northumberland and Montour counties.

This change in fauna between northeastern Pennsylvania and central and southern Pennsylvania suggests the possibility of a barrier zone between the two areas during the deposition of the sandstone over which little or no sand was deposited. Considering the disappearance of the bed in outcrop in western New York and its absence or irregularity in Clinton and Lycoming counties, it may prove that the area in which the New York type of fossils are found lies only east of a belt that runs from Lycoming County across western Tioga County and into the area west of Newkirk, New York. Again the number of breaks found along the outcrop both in New York and eastern Pennsylvania suggeststhe probability that the bed will be lacking under many areas between its outcrops north and south of Tioga County. On the other hand, the mixing of types possibly progressed across the region lying west and northwest of southern Lycoming County. In either case, our present data appears to imply that we may expect to find Oriskany underlying the Tioga region.

Deduced Geologic Section.

The formations exposed at the surface in the Tioga region are assigned to the uppermost Devonian, the Catskill red beds and the partially equivalent and partly older Chemung series of marine sandstones and sandy shales. A considerable thickness of other Upper and Middle Devonian beds may be presumed to intervene between the Chemung and the Oriskany if that formation be present. A generalized, average section of these formations would be:

Generalized, average section.

		Range Feet	Average Feet
Catskill, red beds	-	500 - 1000	750
Chemung, gray to buff sandstone and sandy shale	-	2000	2000
Portage, like Chemung, tends to dark shale and thin limestone (?) near base	-	1200 - 1300	1250
Genesee, black shale	-	150	150
Tully, (?) limestone	-	?	
Hamilton, buff to gray sandstone and shale	-	1000 - 1500	1250
Marcellus, black shale, limy at base	-	50 - 100	75
Onondaga, limestone often cherty	-	50	50
Oriskany, usually coarse, friable sandstone	-	25	25
Helderberg, limestone and shale	-	?	

The thicknesses are largely approximated chiefly through interpolation from adjacent sections in New York and Pennsylvania. The formations are presumedly present only because of their recognition elsewhere.

Age of the Productive Sand.

According to the sections given in the Gaines (No. 92) and Elkland-Tioga (No. 93) folios of the U. S. Geological Survey, the top of the Chemung at Lathrop where the Sabinsville anticline crosses Tioga River is 3,000 feet above tide. The elevation around Sabinsville and for an unknown distance east is given as 2,200 feet above tide. At the location of the well, the top of the Chemung would be somewhere between, say half way, or about 2,600 feet above tide. The Palmer well started at about 1,780 feet, or say 820 feet below the top of the Chemung. It should therefore have penetrated about 1,180 feet of Chemung. Adding 2,775 feet, the average of the beds below the Chemung, would give a computed depth to the Oriskany of say 3,955 feet. This would point to the gas sand being the Oriskany. But it must be recognized and admitted that there are many unknown factors in the problem. Drill records indicate a great thickness of gray or drab sandy shale and shaly sandstone. Such lithology may indicate the Chemung, the Portage, or Hamilton, or may include all of these formations combined, since it is possible that the Genesee and Tully are thinner than inferred or even absent and may not have been recognized by the drillers. It is said that a black shale was struck at a depth of "4,000 feet" and that this overlies a limestone. Assuming that the deduction is correct that the gray to drab series represents Chemung, Portage and Hamilton formations, this black shale should be the Marcellus. If so, the subjacent limestone must be the Onondaga and therefore overlie the Oriskany, the productive sand. However, there is another possible interpretation.

Let us assume that the wells begin higher up in the Chemung or that the formation's thickness is greater than given. This might add several hundred feet to the section above the productive sand. The lithology of the Chemung and Portage, while monotonous, does vary. Occasional limestones and dark shales are encountered. However, it is doubtful if these variations are sufficient to affect the present interpretation. But, assuming that the wells penetrated nearly 4,000 feet of Chemung and Portage, they might then enter black Genesee shale. It is often difficult to distinguish this horizon from the Marcellus, even in outcrops, let alone from well drillings or logs. If the Tully limestone is present below the Genesee, it is at once evident that it would bear the same relation to this higher, Genesee black shale that the Onondaga limestone does to the lower, Marcellus black shale. The Hamilton formation contains, not uncommonly, relatively coarse, friable sandstone strata which might easily pass for Oriskany where fossil content and exact stratigraphic position are unknown or indeterminate.

Summary and Conclusions.

It has been shown that the Oriskany extends in a nearly continuous, horseshoe-shaped outcrop, the curve to the east and the arms extending westward to the north and south of the Tioga area. The attitude of the formation where exposed implies that it dips under the productive region. There is a rather remote possibility, based upon faunal and lithologic evidence, that it may be abnormal or absent in the Tioga district.

The interpolated thicknesses of the formations assumed to be present in the field have been given. From these it is apparent that considerable rock must be penetrated to reach the Oriskany. There may be a possibility of so interpreting this section as to make the productive sand not Oriskany, but Hamilton in age. Such an interpretation depends upon the position of the horizon in the Chemung exposed at the surface where drilling begins. In either case, it is evident that the productive sand may be expected to be capped by a limestone, this in turn by black shale, and the shale overlain by monotonous buff to gray sandy shales 3,000 to 4,000 feet thick.

Finally, since there is a reasonable doubt as to whether the productive sand is Oriskany or Hamilton, although the evidence strongly favors the former, an additional point should be noted. If the sand is Oriskany, further drilling for 25 to 100 feet should go through this horizon. Below it, if the sand is Oriskany, the holes should penetrate an unestimated thickness of the Helderberg formation. This is usually composed of interbedded "waterlimes," some crystalline limestone, and calcareous shale. Some of these beds commonly carry a large ostracod fauna, the individual fossils of which are so small that they can be recovered in a sufficiently well-preserved condition for accurate identification. Such identification would conclusively prove the position of the overlying gas sand; for, if the Helderberg is present, there remains no doubt as to the productive horizon being the Oriskany. If, on the other hand, no Helderberg be encountered, the gas sand should be assigned to a higher horizon stratigraphically, and in that case be tentatively listed as of Hamilton age until further data are obtained. It is important properly to interpret this horizon because of its bearing upon the possible effective depth to which developments may be carried.